U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
DIVISION OF FOREST INSECT RESEARCH

BIOLOGY, ECOLOGY, AND NATURAL CONTROL OF THE BLACK-HEADED BUDWORM

Line Project No. FS-2-I14-10

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GENERAL

In 1957 the cooperative aerial survey, supplemented by ground-checking, revealed light, moderate, and heavy black-headed budworm populations on approximately 237,000 acres of timber in the Cascade Mountains in southwestern Washington. The largest infestation, approximately 180,000 acres, was centered in the Snoqualmie N. F. - Mt. Rainier N. P. area. An egg survey was conducted in this area by research and survey Station personnel during September and October. Egg populations were much lower than anticipated; comparison of number of eggs deposited in 1957 and number of old eggs, believed to be almost entirely of 1956 origin, showed sharp reductions at eight of the ten sampling points. Because of the trend disclosed by the egg survey, direct control was not planned for 1958.

Collections of larvae and pupae by station personnel during 1957 showed considerable effectiveness of insect parasites at certain points, and little or no incidence of disease. It is believed that limited studies during 1958 would show population trends prior to the conduct of the 1958 egg survey, and throw light on the major factors affecting trends. Since the black-headed budworm has not been a problem insect in Oregon and Washington since 1944, an excellent opportunity exists to obtain basic information for evaluating hazard created by future outbreaks, and appraising the need for control.

Because of commitments on a long-term study of the spruce budworm in eastern Oregon, the personnel conducting this study will be severely limited by the amount of time that is available for travel and field work. There is no indication at present whether it will be feasible to complete the proposed work plan this year. However, because the spraying program in eastern Oregon will be terminating certain research efforts on the spruce budworm late in June, or early in July, some time will be available for the study proposed here. It remains to be seen whether the free periods will coincide with phases of the black-headed budworm life cycle for which studies are planned.

OBJECTIVES

The work plan as submitted is for an exploratory study. The line project covering the biological phases outlined (FS-2-I14-10) is not allocated to this station at present. The work plan, however, is pointed toward a comprehensive study at some time in the future, possibly 1959, when the hazard posed by the black-headed budworm would justify a request for inclusion of the line project in this station's activities.

The general objectives of the study are:

1. To provide a sound biological basis for evaluating trends in this region, in relation to the need for direct control. Specific needs are:

   a. Improved sampling procedures for measuring populations.
   b. Better knowledge of the role of natural control factors.
   c. Thorough knowledge of the insect and its habits.

2. To improve ground survey procedures. Specific needs are:

   a. Determination of a minimum satisfactory sample, in relation to size of area being sampled.

   b. Knowledge of the time and methods to be employed according to the amount and caliber of manpower available for a survey.

3. To associate population levels with defoliation and damage and to determine the impact of damage upon stands of mixed tree species.

4. To develop technical procedures to make effective control possible, and to devise methods for evaluating the success of control.

The study is particularly needed because of the lack of intensive studies during past outbreaks in this region. Past history has indicated that the pattern of outbreaks in the state of Washington has differed considerably from the patterns evidenced in British Columbia and in Alaska. It is possible that the effects of feeding may differ with the variations in climate, particularly between the coast belt and the inland forest. At any rate, past outbreaks in the State of Washington have developed rapidly and subsided suddenly. It is important to study these outbreaks as they occur, and before the opportunity passes.

I. METHODS OF SAMPLING FOR THE BLACK-HEADED BUDWORM.

A. Status of information: Several workers in both the East and West have used the 18-inch twig as a foliage sampling unit. During a study in Alaska, the 10-inch twig was used, and for the egg stage counts were expressed on the basis of linear inches of twig (McCambridge, 1954). Sampling during spray operations has been confined to the upper crown third of trees, usually hemlock, in the intermediate crown class. Population densities on a twig basis were determined for three crown levels within the tree (McCambridge, 1954; Brown and Silver, 1957) but no information has been obtained for distribution of absolute populations within the tree crown, based on whole branches. Sampling during an egg survey performed by personnel of this station during 1957 was based on the 18-inch twig, with a subsample of 50 linear foliated inches per twig.

A sampling problem which needs solution is the relation of the distribution of feeding populations to the available food, expressed as number of buds and complement of new needles per bud. This relation would provide basic explanations for the greater degree of damage occurring in the upper crown third, frequently culminating as top-killing (Struble, 1945), and for greater damage occurring on hemlock as compared with intermingled silver fir, Sitka spruce, and Douglas-fir. Preliminary work was performed by Station personnel in 1957 to determine number of shoots per 18-inch twig and number of needles on the average shoot.

B. Objectives: To determine: (1) the distribution of populations attacking the buds within the crown by means of whole branch samples; (2) the relation between populations on whole branches and populations on 18-inch twigs; (3) the adequacy of two foliage sampling units for expressing mean populations by calculating sampling error (at $p = .05$).

C. Methods:

1. Distribution of budworm populations on trees.

In one locality, before egg-hatching, three sample branches will be removed from each crown third of each of ten trees. For each tree, and each crown level the foliated parts of the branches will be placed in 5-gallon ice cream containers, and larvae drawn off to the light. Populations will be recorded for each crown third of each tree. The data will be analyzed for significant differences between populations at the three crown levels.

The sample branches will be held in the ice cream containers until the needles have dropped; branches will then be examined for number of buds on each crown level sample. Populations obtained from the rearing containers will be expressed on the basis of 100 buds. The data will be analyzed for significant difference between populations at the three crown levels.

2. Relation between branch populations and 18-inch twig populations.

   During examinations of 18-inch twigs cut by pole-pruner for larval populations attacking the buds, the number of buds on each twig will be counted and tallied. If counts of larvae per 100 buds are higher than counts obtained from whole branches using 100 buds, it will be obvious that the pole-pruner sample is not representative for the tree. While subsequent sampling will be necessarily based on the 18-inch twig obtained by pole-pruner, because of manpower limitations, the general relation of these estimates to the true tree populations should be established.

3. Adequacy of sampling units in obtaining population estimates.

   It is planned tentatively that 2 twigs will be removed from each of 10 to 15 trees per study plot, depending upon the population level encountered. Intermediate size hemlocks will be sampled, probably at the mid-crown level. During the sampling, populations on each twig will be recorded separately and accompanied by an estimate of the number of new shoots. Population means will be expressed on the basis of 25 twigs and on the basis of 100 buds. Standard error will be calculated for each mean, and used to determine the number of 18-inch twigs or 100-bud samples necessary to obtain less than a 20 percent error at the 95 percent confidence level.

II. EFFECTS OF NATURAL CONTROL FACTORS.

A. Status of information: During past outbreaks in western forests, natural control factors have been instrumental in bringing outbreaks to a close. In regard to an outbreak on Vancouver Island, Prebble and Graham (1945) state: "While parasites played an appreciable part in this infestation..... the wilt disease was primarily responsible for the collapse of the infestation." In addition, McCambridge (1954) states that the fungus Empusa grylli (Fres.) and undetermined disease organisms were very effective in reducing budworm populations, particularly pupae.

The principal parasites of the black-headed budworm are fairly well known. Prebble and Graham recorded about 40 species found in British Columbia, and discussed four species of major importance. In addition, predaceous enemies were noted. Brown and Silver listed parasite species found in 1956 during an outbreak on Vancouver Island. Unpublished lists of parasites reared from the black-headed budworm in the Northeast are available.1/ Most of the parasite species occur both in the Northeast and Northwest.

Recognition of the wilt disease should not be difficult. Most of the parasites encountered can be tentatively identified by the project leader. Specimens for training personnel in identification are available from collections by R. L. Furniss on the Olympic Peninsula in 1944, and by Orr and Carolin on the Snoqualmie N. F. - Mt. Rainier area during 1957. The latter collections disclosed the common species attacking full-grown larvae and pupae, and indicated the comparative abundance of these species.

B. Objectives: To determine: (1) the effects of groups of insect parasites attacking different life stages and the most important species involved; (2) the effects of disease and when it occurs.

C. Methods:

1. Effects of insect parasites.

Studies will be conducted at three plots located in separate spots of moderate to heavy infestation. Collections to determine parasitism will be made for the following stages: (1) the egg (2) early larval stages, principally the 3rd instar (3) full-grown last instar larvae and (4) pupae. Information on the egg stage will be based chiefly on material collected during the egg survey and overwintered at a central location. Eggs will be held on needles in moist sawdust in powder boxes, and parasitized eggs isolated in vials in spring, after these eggs have turned black. The early larval stages (mostly 3rd stage larvae) will be reared in glass-topped boxes on foliage in water, with 50 larvae placed in each box. Full-grown larvae will be reared in cloth-bottomed wooden trays, open at the top but with the upper edge tanglefooted. Pupae will be reared in gelatin capsules. A minimum of 100 specimens for each life stage sampled (with the exception of eggs, where sampling to a minimum number is not always feasible) should be collected at each plot.

1/ Lists are by R. F. Morris for New Brunswick and V. M. Carolin for Maine.

Percent parasitism will be tabulated for each life stage sampled. Among the three plots, correlation will be attempted between aggregate parasitism and the total mortality measured by systematic population estimates.

2. Effects of disease.

The wilt disease is described in some detail by Prebble and Graham (1945). "Diseased larvae exhibit a wide variety of external symptoms, which include commonly a chalky-green appearance with extreme fragility of the skin, besides various shades of discoloration, and in older larvae, complete liquefaction. Active disease in pupae results also in liquefaction of the body contents and fragility of the pupal skin."

During collections of material for parasitism, all larvae and pupae showing disease symptoms will be counted and placed in sterilized vials containing distilled water. Suspect specimens will be sent to Dr. Steinhaus at the University of California for identification of the disease organisms. If disease proves to be a significant factor in mortality, correlation will be attempted between aggregate observed mortality (insect parasites plus disease) and total mortality measured by systematic population estimates.

III. LIFE HISTORY AND HABITS

A. <u>Status of information:</u> Observations in the Snoqualmie N. F. during 1957 indicate the life cycle of the black-headed budworm to be similar to that recorded for Vancouver Island by Prebble (1945) and for Alaska by McCambridge (1954). In both regions, the number of larval instars was determined to be five. Larvae hatching from the overwintering eggs feed for about six weeks, pupation lasts about 3 weeks, and adults survive for about a month. Up to 70 eggs may be laid by one female moth; it has been difficult to obtain reliable estimates of eggs produced per moth in captivity.

B. <u>Objectives:</u> (1) To verify the number of instars for the black-headed budworm and to determine the approximate duration of larval instars and the pupal period during 1958; (2) to determine the approximate number of eggs laid per female.

C. <u>Methods:</u>

1. Occurrence of the life stages and their duration.

At one study plot, after egg-hatching has commenced, collections of life stages will be made once a week and the material preserved in alcohol for subsequent analysis. Because of the conflict with other studies,

probably half of these collections will have to be made by a cooperator. At the end of the season, head capsules of larvae will be measured and a histogram constructed. After head widths have been correlated with certain instars, a development chart will be drawn up to portray the life cycle for 1958.

It is extremely desirable to conduct isolated rearings, starting with first instar larvae, for the best verification of number of larval instars. Because extensive travel on other projects will not permit close attention to such rearings, it is doubtful that these can be conducted during 1958.

2. Determination of the approximate number of eggs deposited per female moth.

   During late summer, when moths commence to appear in the field, a search will be made at intervals for pairs in copulation. Each pair found will be placed in a single rearing cage with fresh foliage in water, and held for a month for egg deposition. The type of cage to be used is yet to be determined; possibly the plastic cage devised by Randall (1957) will be used.

IV. DAMAGE.

A. Status of information: Studies of an outbreak on Vancouver Island, B. C., during the period 1940-44 (Prebble and Graham, 1945) initially showed very little mortality of commercial timber. Heavy infestations in stands of western hemlock for at least two or three years resulted in partial stripping of the upper crown levels, with the loss of practically all currently produced foliage and about one-third to three-fourths of the accumulated old foliage produced in previous years. A large proportion of the buds were killed and dying of small twigs and branches was common. Radial increment was usually reduced appreciably, the dominant and codominant trees generally being more noticeably affected than trees in the intermediate crown class. Core analyses showed silver fir to be affected less severely than western and mountain hemlock. During 1946, after the outbreak had ended, extensive tree mortality was observed in the Salmon and Adams River country over an area of 40,000 acres and was classified as moderate or heavy on 25,000 acres (Richmond 1946). Other areas showed good recovery of defoliated stands.

   The greatest hazard was considered to occur in extensive young stands of western hemlock. Susceptibility of young stands was attributed to the fact that tops of the trees consist mainly of new succulent foliage, attractive to the budworm, and therefore liable to complete stripping.

Similar observations were made by McCambridge in Alaska (1954). Comparison of damage resulting from feeding on western hemlock and sitka spruce indicated that sitka spruce suffered less damage and recovered more rapidly than western hemlock. McCambridge was particularly concerned with the possibility of predicting damage, and attempted to correlate number of eggs deposited per 10 twig-inches with subsequent defoliation, using small suppressed trees. While this was successful for the trees actually sampled, it was found that populations on these trees were not indicative of populations on overstory trees. Populations on open-grown small trees were more representative of those on the overstory trees, but no correlation was established. For small open-grown trees, concentrations of 0.1 egg per twig-inch did not produce serious defoliation; 0.27 eggs per twig-inch did result in noticeable defoliation.

B. Objectives: To correlate number of eggs hatching on branch samples with subsequent defoliation occurring the same season.

C. Methods: Initial populations on sample branches from ten trees will be determined as part of the population distribution study (see I-C-1). At the time these branches are cut, estimates of past defoliation will be made for each crown third of each tree, using field glasses. A check will be made as to the accuracy of these estimates and the relative amount of bud-kill as the foliage material is boxed. At the end of the feeding period, after most of the dead and discolored needles have been washed off the branches, estimates of defoliation will again be made, using field glasses. Sample branches will be removed from half of the trees, using the pole-pruner if possible, to determine the incidence of bud-kill.

Attempts will also be made to correlate estimates of 3d instar and 5th instar populations with resulting damage. In the event of differential survival between plot areas, these estimates might prove more useful than those for larvae entering the buds.

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